AD-A135 261 INSTRUCTIONAL PSYCHOLOGY 1976 - 1981(U) FLORIDA STATE UNIV TALLAHASSEE R M GAGNE ET AL. JUN 82 N66001-81-C-0456 1/2

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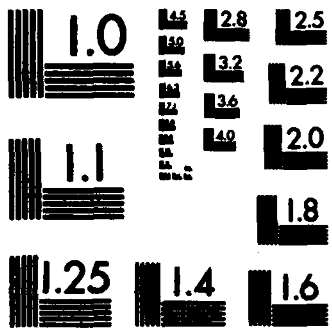
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INSTRUCTIONAL PSYCHOLOGY

1976 - 1981

Robert M. Gagné and Walter Dick

Florida State University

A report to the U.S. Navy Personnel

Research and Development Center

San Diego, California

June, 1982

Contract No. N66001-81C-0456

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Introduction

The field of research encompassed by instructional psychology has become large, as noted by Resnick (1981), and has continued to grow during the five years prior to July 1981. Since one of us participated in preparing the original article with this title (Gagné & Rohwer, 1969), he can state with some assurance that the task of examining the current published work in the field cannot be approached with the techniques possible in that earlier time, nor with the same commitment to comprehensiveness. Resnick's remark that much of instructional psychology is now within the mainstream of cognitive psychology also recognizes a circumstance that must be taken into account in the preparation of an article such as the present one.

Problem

Our problem is to review research which can be categorized as

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[1] This work has been supported in part by Contract #N6601-81C-0456 with the U.S. Navy Personnel Research and Development Center. We thank Felix Bongjoh, Dale Farland, Peggy Perkins, and Katherine Sink for assistance in location and review of items in the literature. The views and conclusions contained in this document are those of the authors and should not be interpreted as reflecting the views, expressed or implied, of the Navy Personnel Research and Development Center, or the U.S. Government.

instructional psychology, during the years 1976-1981, to identify major trends and issues in this research, to summarize methods and findings, and to comment critically on the results and their implications for instruction.

Purpose

The purpose of this inquiry is to summarize the gains that have been attained in the understanding of instruction through research efforts reported during the period of this review. An equally important purpose is to identify areas of research which have been initially explored, and which show promise of yielding good returns in furthering the development of methods for instructional design and delivery.

We attempt to report and reflect upon some of the major trends in the field, within an organization that intends to describe the major points of influence research may have upon instruction. Since the most recent article in the series on this topic (Resnick, 1981) sought to review the research on instruction in particular school subjects, We have tried ~~instead~~ to pick up the threads of inquiry on more general psychologically oriented areas that cut across subject-matter categories.

Background

A large amount of research effort in recent years has been devoted to exploration of relations between student characteristics and instructional outcomes. We find it instructive to note that some kinds of student characteristics are alterable by periods of instruction of course length or less, while other kinds are not, or at least have not been shown to be. The instructional implications of these two kinds of personal qualities are, of course, quite different. Some student

attributes may be directly taught; for these, the research question of greatest interest is how instruction may be constituted for best results. Other personal qualities cannot be taught, so far as is now known, and these can only be taken into account in some manner or other so that they will either enhance or fail to hinder the operation of other instructional variables. Vigorous search has continued for combinations of student characteristics and instructional conditions which relate to each other as attribute-treatment interactions (ATI) of the disordinal sort, carrying the implication that contrasting instruction may be most successful when delivered to students with contrasting personal qualities.

Research on instruction often takes the teacher as the focus of interest. In contrast to an earlier period in which questions were phrased in terms of teacher qualities (intelligence, experience, etc.), current studies tend to deal with <u>teacher procedures</u> and <u>teacher activities</u>. Of course, teachers must be competent to carry out these procedures, and assessment of their competence remains a matter of interest. Included in the category of teacher techniques and procedures are such subtopics as the kinds and amount of student-teacher interaction, clarity of oral communication, teacher modeling, and methods of tutoring.

Of central importance to instructional psychology are the <u>events of instruction</u>, and the manner in which they are designed and delivered. A number of investigations deal with the effects of clearly expressed goals and objectives as part of instructional content. While most studies employ printed texts as the mode of delivery, there is continuing interest in other modes, including audio-visual instruction. Within the realm of printed instruction, the utilization of pictures has received much

attention, as has the continuing issue of varieties of practice and feedback techniques, and the use of test-like events within the instructional content. In view of the theoretical importance of these variables, studies that verify causal relationships with measures of learning outcomes are of particular interest.

We begin our chapter by taking note of some general works which have contributed to the definition of the field of instructional psychology, the description of some of its historical roots, and the identification of its boundaries. A following section provides an account of instructional theories that have newly appeared or attained some prominence during the period of this review, and another deals with some concepts of cognitive psychology of recent origin that may be expected to influence instructional theory and practice. The body of research on student characteristics, teacher procedures, and instructional techniques is examined in terms of major trends. As a final section, we describe and consider critical issues in the application of instructional psychology.

We made an attempt to gather a variety of information on applications, recognizing that there are many organizations whose business it is to carry out applied work in the design of instructional content and delivery. These organizations include specialized divisions of industrial concerns, military training agencies, independent research and development firms, and university centers. Our efforts in this direction were no more than minimally successful. Although we were able to verify a general awareness that instructional psychology has widespread applicability to concrete problems, the constraints of time made it impossible for us to follow up many of the suggestions we received. It is our impression that a

descriptive account of instances of application would be a highly desirable product, and that something like five man-years of effort would be required to prepare it. For the present chapter, we are able only to include four clusters of projects which exemplify applications in as many areas.

General Works

Theoretically-related concepts described by investigators who have decided to call themselves "cognitive psychologists" greatly enriched the domain of learning and memory psychology, from which many of the organizing ideas of instructional psychology must be drawn. Prominent among books which will doubtless serve as key references for a span of years are the series of handbooks edited by Estes (1975, 1976a,b, 1978a,b) and the 5th edition of Theories of Learning by Bower & Hilgard (1981). A theme-setting article by Simon (1980) relates this field to cognitive science as a "science of the artificial." Other books of particular value in presenting and clarifying information-processing views of learning and memory, appearing in this time period, are by Bransford (1978), Glass, Holyoak & Santa (1979), Klatzky (1980), Lachman, Lachman & Butterfield (1979), and Anderson (1980). This listing is by no means exhaustive, nor does it include many excellent edited volumes containing individual chapters, which have made equally valuable contributions to the field.

Works of historical and programmatic interest to instructional psychology are of several sorts. Many prominent investigators in the field contribute such articles to the Educational Researcher. An insightful article bringing the psychology of learning up to date was

offered by Greeno (1980). Glaser has made several influential contributions serving to define the field of instructional psychology, including articles outlining varieties of research questions (1979, 1982), the first volume of a series of books containing contributed chapters (1978), and a collection of essays relating research and development to school change (1978), dedicated to Ralph Tyler. Another noteworthy publication of general interest is a book of case studies sponsored by the National Academy of Education, exemplifying the influence of research on education (Suppes, 1978), which includes evaluative essays on mental measurement and the contributions of E. L. Thorndike, Piaget, Freud, Skinner, and others. A recent book edited by Farley & Gordon (1981) offers up-to-date reviews of a number of areas of instructional psychology, including individual differences, intellectual development, learning and instruction. A new journal, Journal of Instructional Development, launched during this period by the Association for Educational Communications and Technology, Inc., appears to have achieved a favorable foothold, and frequently includes articles partaking of instructional psychology. Of particular interest to university instructors is the volume collection of outstanding articles on learning and instruction, edited by Wittrock (1977).

Instructional psychology reaches into the fields of adult education and higher education. Cross (1976) reviews evidence of the effectiveness of various kinds of programs and instructional adaptations aimed at college students. These include remedial education, programs for individualizing instruction (including computer-based models), mastery learning and self-paced modules (PSI). A more recent work (Cross,

1981) is devoted to problems of instruction with adult learners--who participates, why or why not, and some implications of increasing participation in lifelong learning. A variety of lines of research on adult learning are captured in a book edited by Howe (1977). Despite the high quality of many of these efforts, one comes away from the book with the impression that some of the most important questions about adult learning have yet to be formulated.

Instructional Theories

Theories of instruction attempt to relate specified events comprising instruction to learning processes and learning outcomes, drawing upon knowledge generated by learning research and theory. Often, instructional theories are prescriptive, in the sense that they attempt to identify conditions of instruction which will optimize learning, retention, and learning transfer. Originators of such theories sometimes refer to Simon's (1969) description of "sciences of the artificial" as characteristic of their efforts. To be classified as theories, these formulations may be expected, at a minimum, to provide a rational description of causal relationships between procedures used to teach and their behavioral consequences in enhanced human performance.

Different from instructional theories as so defined are models of instructional design. While naturally related, the latter have the purpose of identifying efficient procedures by means of which instruction may be designed. It is not necessary for an instructional design model to give a rational account of causal relations of instructional events to learning processes, although of course such relations are usually implicit, and may be explicit. Typically, models of

instructional design begin with needs assessment and specify a number of stages of design and development activities including tryout, evaluation, and costing. Medial states such as "choosing instructional strategies," "selecting media," and "development of course materials" obviously depend upon one or more instructional theories, which in different models may be given more or less prominence. Examples of instructional design models which have seen publication during the period of this review are those by Briggs & Wager (1979), Dick & Carey (1978), and the <u>Instructional Systems Development</u> model described by Branson (1979). Two volumes edited by O'Neil (1979a,b) deal with procedures and issues in instructional system development. A critical review of 40 models of instructional design is given by Andrews & Goodson (1980).

<u>Gagné-Briggs</u>

A Gagné-Briggs (1979) theory of instruction, based in part upon the work of Gagné (1977b), begins with a taxonomic framework of learning outcomes, considered essential for an understanding of human learning as it occurs in instructional settings. Learning outcomes, conceived as acquired capabilities of human learners, are classified as (a) verbal information, (b) intellectual skills, (c) cognitive strategies, (d) motor skills, and (e) attitudes. Although independently derived, these categories have an approximate correspondence with those of Bloom and his co-workers (Bloom, 1956). The first three of these categories also correspond with those in the psychology of cognition and learning, named, respectively (a) declarative knowledge,

(b) procedural knowledge, and (c) cognitive strategies (Anderson, 1980; Bower, 1975).

In addressing the matter of instruction, the Gagné-Briggs theory proposes that each of the categories of learning outcome requires a different set of conditions for optimizing learning, retention, and transferability. Optimal conditions include external events in the learner's immediate environment, usually called "instruction," and internal conditions acting through the learner's working memory, which have their origins largely in previous instruction (Gagné, 1977b). It is the contention of this theory that traditional factors in learning, such as contiguity, exercise, and reinforcement, while of undoubted relevance, are much too general in their applicability to be of particular use in the design of instruction. Instead, internal and external conditions must be specified separately for the learning of verbal information, for intellectual skills, and for each of the other categories of learned capabilities.

The processes of learning assumed by the Gagné-Briggs theory are those included in the information-processing model of learning and memory, as described by Atkinson & Shiffrin (1968) and employed in essential aspects by several other memory theorists (Greeno & Bjork, 1973). Prominent among these processes are attention, selective (feature) perception, short-term memory, rehearsal, long-term memory storage, and retrieval. Externally, reinforcement via informative feedback is also assumed (Atkinson & Wickens, 1971; Estes, 1972). From these processes are derived both the internal and external events which make possible effective learning and retention. Instruction is defined

as a set of events external to the learner which are designed to support the internal processes of learning (Gagné, 1977c). Specifically, these events are conceived as taking place in an approximately ordered sequence as follows: (a) gaining attention, (b) informing the learner of the objective, (c) stimulating recall of prerequisites, (d) presenting the stimulus material, (e) prov'iing "learning guidance," (f) eliciting the performance, (g) providing feedback, (h) assessing the performance, and (i) enhancing retention and transfer. While all of these events are considered to be involved in each act of learning, it is noted that as novice learners become more experienced, the events tend to be more frequently provided by the learners themselves rather than by external agents. As factors influencing learning, many of these events are included in other instructional theories (Bloom, 1976; Merrill et al, 1979) and share with them evidences of their individual causal effects.

Several characteristics of this perscriptive instructional model make it distinctive from others. In the first place, it is based upon identified aspects of information-processing theories of learning (Bower & Hilgard, 1981), including the human modeling concept of Bandura (1969). The model does not attempt to propose new theory pertaining to learning and memory, but only to use existing theory as a basis for the conceptualization of instruction. (A particulate exception is the theory of learning hierarchies, Gagné, 1968, 1977b). Secondly, the theory is comprehensive, in the sense that it attempts to include all of the kinds of learning outcomes to which instruction is usually addressed. This is the basic significance of the theory's proposal of five kinds of

learning outcomes, including attitudes and motor skills as well as cognitive capabilities. A third distinctive feature is the fact that the theory provides a rational basis for instruction as a set of events which interact with internal learning processes, and also with previously acquired contents retrieved from the learner's long-term memory. The inclusion of these characteristics make it possible for this theory to deal with instruction of many forms in a great variety of settings.

Bloom

The model of instruction described as *mastery learning* (Block, 1971; Bloom, 1971, 1981) continues to receive research attention. Its rationale is derived in part from the model described by Carroll (1963), and includes these major variables: aptitude (time required to learn), quality of instruction, ability to understand instruction, perseverance (time the learner is willing to spend in learning), and opportunity (time allowed for learning). In more recent accounts (Bloom, 1976) the theory has come to give primary emphasis to "alterable variables" for schooling, which are (*a*) cognitive entry behaviors, (*b*) affective entry characteristics of students, and (*c*) a number of specific factors making up the quality of instruction. Among the most prominent contributors to instructional quality are student participation and the corrective feedback which follows.

Emphasis on the study of alterable variables, as opposed to the relatively stable ones often called aptitudes or abilities, is likely to have a stimulating influence on instructional research. This

strand of the theory is well developed and well documented with a considerable body of evidence (Bloom, 1976), including some that has been more recently assembled by some of Bloom's students (1980). The "micro-level studies" referred to by Bloom constitute a substantial part of the corpus of instructional psychology, as reflected in this article and those that have preceded it. By this time there are massive amounts of research findings about the effects of cognitive prerequisites, distinctive cues, learner practice, and corrective feedback on learner achievement.

The second strand of Bloom's theory states a more radical hypothesis. It proposes that individual differences in achievement can be reduced in their amount of variation, over time occupied by successive learning units. Such reduction in variability, it is stated, can occur as those students who are originally low achievers are given high quality instruction, including corrective feedback, and are then permitted to take more time to reach mastery. When this procedure is carried out over successive units of instruction, the theory says, the lower-achieving students will become more like the higher-achieving students. As this begins to happen, it is possible that as achievement improves (with quality of instruction), secondary effects will come from improvements in cognitive entry behaviors and in affective entry characteristics. Anderson's (1976) study showed that eighth grade low-achieving students in matrix arithmetic, when given quality instruction according to mastery learning methods, reduced their need for extra on-task time from an additional 66% on the first unit to

30% on the second, and to 5% on the third. Additional studies designed to test this variation-reduction hypothesis are awaited.

The investigation of alterable variables is obviously an effort of considerable potential value for education, through the promise it holds for the design of high-quality instruction. Variables included in the theory are derived from evidence concerning "what makes a difference" in the determination of instructional outcomes. Bloom's theory is thus an empirically-based theory, of the sort that Carroll (1965) called "econometric." While each alterable variable is considered to have a causal effect on achievement, the theory puts forward no hypothetical learning processes, nor processes which seek to explain the action of instructional variables on learning and retention. In this respect it differs from a number of other theories.

<u>Merrill</u>

Merrill and his collaborators (Merrill et al, 1979; Merrill et al, 1977; Reigeluth et al, 1978) have described a prescriptive theory aimed at instructional quality. To begin with, these authors consider that quality of instruction depends upon the adequacy and the consistency with which the purpose of instruction is represented in objectives, the consistency and adequacy with which these are represented by tests, and the consistency and adequacy with which these outcomes are represented in the instructional presentation. Dealing with the outcomes of (<u>a</u>) concepts, (<u>b</u>) principles, and (<u>c</u>) procedures, the theory holds that there are three levels for the representation of what has been learned, and what is to be tested: remembering an instance, remembering a generality, and using a generality. A test-presentation consistency

table indicates which "primary presentation form" should be used for each of these levels of test items. Thus, for example, for remembering a generality, the generality presentation form is appropriate, whereas the instance presentation form is not.

Within the confines of proper presentation forms, instructional presentation can be more or less adequate depending upon what strategies are used. For concepts, some strategies that are considered relevant are listed. They include the following: (*a*) providing immediate informative feedback; (*b*) isolating the presentation form by separating it from other material and clearly labeling it; (*c*) giving helps, such as mnemonic aids, attention focusing, algorithms; (*d*) providing an adequate sampling of instances; (*e*) indicating divergence (differences) of instances; (*f*) using a range of difficulty levels; (*g*) arranging instances so as to favor matching of common properties. Similar strategies are listed as applicable to the presentation of the other two categories encompassed by the theory, principles and procedures.

Some of the instructional strategies suggested by this theory have received empirical verification by such investigators as Tennyson et al (1975), and Markle & Tiemann (1974), among others. While all the suggestions appear to be soundly based when judged against known research findings, specific design of strategies for the three categories of outcome has not as yet been described. It would appear that such strategies may best be viewed as providing a basis for a checklist of points to keep in mind while designing instruction. The relation of instructional strategies to learning theory is not given. A prominent feature of this theory is actually an instructional design procedure,

including its insistence on precise consistency in the sequence of instructional derivation: from goals to objectives to tests and to instructional presentations.

Reigeluth

An Elaboration Theory of instruction has been described by Reigeluth and colleagues (Reigeluth, 1979; Reigeluth et al, 1978; Reigeluth & Rodgers, 1980). This theory intends to deal primarily with "macro" strategies for organizing instruction, those that pertain to the sequencing and interrelating of topics within a course. Although its basic rationale is partly shared with Merrill's instructional theory (see the previous section), the latter is considered to deal with "micro" strategies for the design and presentation of material within a topic.

The kinds of instructional content with which Reigeluth's theory deals, aside from "rote facts," are concepts, principles, and procedures. The general theoretical conception of instruction is compared to viewing a scene with the use of a zoom lens. Beginning with a wide-angle view, one gradually increases the detail and complexity of parts by zooming in on them. Following this, one must again return to the wide view in order to integrate the specific information with the larger whole and to review previous instruction. Periodic review and synthesis are considered important aspects of the theory which have the effect of enhancing learning, retention, and transfer. The wide-angle view has the purpose of epitomizing the organizing content, which is given the meaning of "teaching a small number of concepts" by the use of applications.

When instructional sequences are being designed, the presentation of an epitome is followed by the teaching of an operation, and this in turn is followed by what is called the "expanded epitome." An instructional sequence designed in this manner would have the following steps (Reigeluth & Rodgers, 1980): (a) select all the operations to be taught (by performing a task analysis); (b) decide which operation to teach first; (c) sequence all the remaining operations; (d) identify the supporting content; (e) allocate all content to lessons and sequence them; (f) sequence the instruction within each lesson; and (g) design instruction on each lesson and expanded epitome.

Obviously this theory incorporates a number of ideas that are common to other prescriptive models. It utilizes both information-processing task analysis (P. Merrill, 1976) and learning hierarchies (Gagné, 1977a,b), and it claims to use to advantage the idea of subsumption (Ausubel et al, 1978). It accepts the procedures of "microstrategies" for component lessons, as involved in the theory of M. D. Merrill (previous section). The theory's outstanding novel contribution appears to be the prescription of frequent "zooming" from the most general view of the content to be learned, to selected specific details, making provision for the learning or recall of prerequisites, returning to the general view once more, with provision for review and practice. Repeated application of this sequence is proposed, to make it possible for the learner to acquire an increasingly elaborate view of the subject. There appears to be some compatibility with the idea of the "spiral curriculum" (Bruner, 1960) which included the proposal of periodic return to main concepts by review and elaboration. Ausubel's

notion of progressive differentiation (Ausubel et al, 1978), advocates beginning instruction with the larger, more general and unifying ideas, before proceeding to detailed concrete ones. Gagné & Briggs (1979) place most weight on relevant prior learning as a basis for sequencing instruction. In all of these cases, differences from the sequencing prescription of the Elaboration Theory may be primarily matters of emphasis.

Case

A Neo-Piagetian theory of instruction has been proposed by Case (1978a,b,c). Instructional implications are derived from a theory of intellectual development which holds that the sequence of behavior that emerges during each of the major stages of intellectual development (Piaget, 1970) depends upon the appearance of increasingly complex cognitive strategies ("executive strategies"). Two kinds of influences are considered to explain the succession of strategies within each stage. One is the acquiring of strategies through experience, or through encounters with planned instruction. The second factor is a gradual increase in the size of working memory (sometimes called M-power). Case proposes that this increase in working memory results from automatization of the basic cognitive operations of which the learner is capable. Furthermore, the cognitive strategies available at each developmental stage must be assembled in working memory from components available at the previous stage. Such assembly is possible only when the operations of a previous stage have attained an appropriate degree of automaticity.

Implications for instruction of this developmental theory are phrased in terms of instructional design. A first step is to identify the goal of the task to be performed. Following this, a series of operations is mapped out by means of which the learner may reach the goal; it is suggested that personal introspection or "expert" protocols may be used. The next step is to compare this series with the performance (and reported thoughts) of skilled performers. A second phase of instructional design is to assess students' current level of functioning, discovering by clinical questioning or otherwise how the "novice" approaches the task. Instructional design is then undertaken, including exercises that demonstrate to the learner the inadequacies of his current strategy, and providing an explanation of why the "correct" strategy works better. This is followed by the presentation of additional examples using the new strategy, and practice with them. Throughout the process of developing instruction, careful attention is paid to minimizing cognitive complexity, in view of the learner's M-power as a limiting factor.

Considering the circumstance that this instructional theory has seen a gradual development from the fundamentals of Piaget's work, its departures from traditional interpretations of that work are remarkable. For one thing, it acknowledges that the Piagetian structural analysis of conventional academic tasks is virtually impossible, and must be replaced by an analysis of executive strategies. Secondly, a definite distinction is drawn between theory which deals with development of intellectual competence, and procedures which are concerned with adapting the content of instruction to the operational level of the learner.

A distinctive feature of this instructional theory, one which retains the theme of the Piagetian tradition, is its proposal that existing cognitive strategies of uninstructed students be discovered, analyzed, and used as a basis for contrast with the more efficient executive procedures to be newly taught. A further characteristic to be noted, common to "developmental" theories, is its exclusive concern with the learning of cognitive strategies, with consequent inattention to other kinds of learning outcomes.

Collins

Collins (1977) describes a theory of Socratic Tutoring which he considers capable of teaching new knowledge and also the skills necessary for applying that knowledge to new problems and situations. The theory is conceived to be particularly useful in developing an intelligent CAI system (Collins et al, 1975). The teaching dialogue of such a system is best characterized as a blend of diagnosis and correction strategies; the tutor probes the student's understanding and uses errors as clues to misconceptions. Applications of these ideas in conveying an understanding of such topics as evaporation, the weather system, and the effects of water and air currents on world climates are described by Stevens & Collins (1981).

In this tutoring system, the tutor's questions are guided by a number of rules, beginning with "ask about a known case, if it is the start of a dialogue, or if there is no other strategy available" (Collins, 1977). Twenty-four such rules are described, 15 of which are "formulation rules," and the remainder "application rules." Collins illustrates their use in tutoring dialogues on growing grain,

population density, and other topics. Analysis of these and other protocols indicate that students learn new information, make functional inferences, and learn to "reason" about the problems presented in the tutoring situation.

The Socratic Tutoring theory proposes that suitably designed CAI routines can make it possible for students to carry out problem-solving exercises in areas of knowledge that are initially unfamiliar to them. In so doing, such routines not only convey new organized knowledge, but also permit the student to practice reasoning strategies relevant to the new content being learned. While evidences of learning exist, it appears evident that additional research will be needed to illuminate many as yet unanswered questions about this promising theory. Two that suggest themselves immediately are: (a) what are the effects of student characteristics (age, intelligence, prior knowledge, etc.) on the learning outcomes; and (b) what transferable strategies and skills result from this method of instruction?

Rothkopf

A theory of instruction proposed by Rothkopf (1981) emphasizes empirical variables such as those suggested by Carroll (1963), but in addition provides a theoretical rationale for their inclusion as factors which promote learning. The factors identified are considered to increase the probability of success in attaining a designated learning objective. There is, first, disparity between the defined performance outcome and the instruction itself, whether the latter is verbal or in some other form. Disparity thus describes the kind of transformation the student must perform on the instruction, in order to achieve a

successful performance. This means specifically that the student must have the ability to engage in suitable mathemagenic activities (Rothkopf, 1965, 1971). These activities depend on the learner, but can be modified by various instructional means such as the use of adjunct questions. A third set of factors consists of the intellectual capabilities of students. The difficulty of processing instructional information is reduced when the elements of these capabilities are familiar. Such familiarity, in turn, is derived from the previous instruction-relevant experience of the learner. Other resource limitations in this category are the capacity limits of the learner.

This instructional theory is discussed within a larger framework of what makes a difference in school instruction. In this context, factors such as frequency of instructional events (I), attendance-compliance (A-C), and retrievability (R) are added. Rothkopf states his purpose of describing a molar theory rather than a molecular one. Actually, one gains the impression of a somewhat mixed set of variables: the first three plus retrievability possess theoretical rationales relating instruction to learning, whereas those dealing with frequency and time are management factors that have confirmation in recent empirical studies (e.g., Denham & Lieberman, 1980). The theoretical concepts of this theory are not differentially applied to different kinds of learning outcomes; otherwise, they show considerable resemblance to those of other instructional theories of the cognitive variety.

Markle & Tiemann

If the question is raised, "What has become of programmed instruction?" the answer is, it has lost an "m," but otherwise has been

carefully nurtured and greatly elaborated by Markle & Tiemann (1974, 1978; Markle, 1978). As an instructional theory, it is applied to a number of kinds of learning outcomes, categorized as psychomotor, simple cognitive, and complex cognitive. The last of these includes concepts, principles (rule application) and strategies. The theoretical concepts included in this theory are primarily three, familiar in this field of instructional design: (a) active responding, (b) "errorless" learning, and (c) immediate feedback. These principles are described in great detail, with many examples for the learning of concepts, rules, and procedural rules. Instruction for other outcomes, such as verbal knowledge, employs the same principles, and additional conceptualizations of learning processes appear to be considered unnecessary. For instruction in intellectual skills and problem solving, particularly when self-instructional materials are appropriate, both theory and design procedures are developed with remarkable thoroughness.

Scandura

Over a period of fifteen years or more, and in many articles and books, Scandura (1977a,b, 1980) has described the various characteristics, predictions, and limitations of structural learning theory. This theory deals with intellectual competency. It proposes that competence underlying any particular problem domain can be represented in terms of finite sets of rules. As for the rules themselves, each is conceived as having the three features of (a) a domain, or set of conditions to be satisfied by inputs; (b) a range, or set of conditions characterizing the outputs the learner expects the rule to produce;

and (c) an operation, or procedure, which, when applied to the contents of the domain, generates a unique output. Expanding upon this conceptual basis, structural learning theory proceeds to deal with the control process called "goal-switching" and its application to the utilization of rules and higher-order rules. When the learner fails to find the rules to achieve problem solution, the goal-switching process directs the search for higher-order rules which generate other potential solution rules. When applied, the newly generated rule is added to the set of available rules, and the search reverts to the next lower level.

Structural learning theory has particular implications for cognitive processing load and speed, for the analysis and assessment of individual learner competence, and accordingly for the systematic design of instruction aimed at establishing problem-solving capability (Scandura, 1977a). Almost all of its examples and its predictions are couched in mathematical terms. It may best be viewed, therefore, as a theory of rule learning and rule application. While well developed in those domains, its scope does not appear to encompass the learning of such capabilities as foreign language, historical knowledge, a good tennis serve, or preference for abstract art.

Landa

Landa's (1976) second book expands upon the theory of algorithmization of instruction as originally described in his work (translated from the Russian) of 1964. Defining and using algorithms has the purpose of assuring instructional effectiveness and efficiency. The basic properties of algorithms are as follows: (a) specificity, which

means that all actions of the user of an algorithm are unambiguously determined by statements of rules; (b) generality, implying that the algorithm is applicable to an entire set of problems belonging to a particular class; and (c) resultivity, indicating that the algorithm is always directed toward achieving the sought-after result. These characteristics appear clearly to equate algorithms with rules, or with rule systems embodied in procedures. Landa discusses the differences between algorithmic procedures and heuristics, and particularly the differences in mental operations which characterize creative behavior. In addition, he provides examples of algorithmic instruction in geometric problem-solving, in foreign language teaching, and in several other instructional areas.

In common with a number of other instructional theories, Landa's model of effective instruction calls for systematic analysis of the learning task, precise definition of the procedures (rules) to be taught, and the presentation and exemplification of these procedures to the student in the clearest and most direct possible manner. To Landa, algorithms are the "basic" aspects of instruction, which pave the way for heuristic learning and creative thinking.

Karplus; Lawson

It is noteworthy that investigators of education in scientific subjects continue the trends noted by Resnick (1981). Some of their theories and empirical findings are reported in the 1980 Yearbook of the Association for the Education of Teachers in Science (Lawson, 1980). While continuing to be cognizant of evidence indicating the gradual nature of intellectual development (Karplus, 1980), these

researchers seek to interpret and apply evidence that will improve students' ability to think in ways related to the reasoning exhibited by scientists. Lawson & Lawson (1980) include in their instructional recommendations (*a*) testing the truth of categorical propositions, (*b*) testing hypothetical causal propositions, and (*c*) strategies of hypothetico-deductive reasoning. In general, most investigators in this tradition suggest the use of concrete problem-solving exercises representing particular kinds of reasoning to support the development of critical and creative thinking. As instructional theory, these ideas are narrowly oriented, although they are based in most instances upon solid evidences of student performance.

Suppes

Suppes (1978) discusses the idea of "global models" of instruction, so-called because they deal with such variables as students' mean rates of progress through a topic course. At the same time, such models ignore the details of responding that are traditionally of interest to the instructional psychologist. Findings of global studies may be used to indicate, for example, the proportion of time which should be devoted to the teaching of arithmetic at the fifth-grade level; or within an arithmetic course, how much time should be devoted to computation and how much to problem solving. The aim of such investigation is to permit use of the model for optimization of outcomes.

A set of axioms is stated as a basis for deriving the general equation of the theory, as follows: $y(t) = bt^k + c$. (The y variable refers to grade or course placement of the student; t is the student's time in the system; b, c, and k are parameters to be estimated for each

student.) Trajectories of students in several schools for the deaf and one school for Indian children, in CAI in mathematics, reading, and language arts were used to test the fit of data to theoretical curves (Suppes et al, 1975, 1976). Another test of the theory is provided by data from the Nicaragua Radio Mathematics Project (Searle et al, 1976) relating to the problem of optimizing review exercises within each 25-minute radio lesson, and within the approximately 150 lessons per school year. It is noteworthy that the predictions made by global models are not restricted to subjects of the elementary school, as indicated by application of the trajectory model to a university-level course on introduction to logic (Larsen et al, 1978). For investigators who seek to explore global predictions for optimizing various aspects of instruction and curriculum patterning, these models appear to have considerable usefulness.

Summary of Instructional Theories

Theories of instruction, as contrasted with models of instructional design, attempt to construct rational links between the processes of learning and the stimuli impinging on the human learner, keeping in mind certain measures of learning outcome such as retained or applied knowledge, skilled performance, or expression of attitude. Models of instructional design are often highly systematic (Andrews & Goodson, 1980), yet the degree of specificity with which they relate to processes of learning may be slight. Instructional theories, on the other hand, are most adequate when their conceptualization of the causal relations between external stimulation and internal processing is spelled out in detail.

The instructional theories we have reviewed differ from each other greatly in the precision with which they specify causal relations of instructional events to learning processes. At one end of the spectrum, the Gagné-Briggs theory proposes a specific relation between each of nine "instructional events" and an internal process that event is hypothesized to support (i.e., activate or maintain). At the other end are theories like those of Carroll and of Bloom, which come to many of the same conclusions based upon empirical findings about variables comprising the "quality of instruction." It seems likely that these two types of theory can readily be brought into consonance, and that the twin foundations of theory and empirical findings can be utilized for both.

A prominent difference among theories is their treatment of varieties of learning outcomes. The five different results of learning conceived by Gagné and Briggs as requiring distinct instructional conditions are ignored in one way or another by other instructional theories. One way of neglecting these different outcomes is to construct a theory narrowly oriented to one type (as the theories of Karplus or Lawson or Case are to "intellectual development"). Another way is to employ different outcome categories, such as concepts, principles, procedures (Merrill et al), or concepts, principles, and strategies (Markle & Tiemann). Somehow, it would seem, it will eventually be necessary for instructional theories to encompass the full variety of learning outcomes implied by such terms as "cognitive," "motor," and "affective."

Yet to be developed in instructional theories are adequate

conceptualizations of how instruction can be made to support the retention and transfer of what has been learned. Some of the newly appearing theoretical ideas of cognitive learning theory, as discussed in the following section, will undoubtedly have substantial effects on these aspects of instructional theories. For example, the ideas of automatization, knowledge compilation, and the formation of schemata, carry the implication that theorizing about instruction must go beyond the promotion of a state of initial learning. Influenced by the current emphasis on evaluation of instructional programs, theorists may be expected to give increased attention to retention and learning transfer as goals of learning.

Contributions of Cognitive Psychology

By this time, it has become entirely customary for research questions about the psychology of instruction to be phrased in terms of the concepts of cognitive psychology (Bower & Hilgard, 1981; Estes, 1975, 1976, 1978a,b). Accordingly, instructional procedures are often described in the language of cognitive psychology, such as short-term and long-term memory, semantic encoding, retrieval, and the like (cf. Gagné, 1977; Merrill et al, 1981). During the period covered by this article, certain concepts of cognitive psychology have become prominent which are of undoubted relevance to instruction.

Cognitive Strategies

During the period of this review, considerable research effort has been devoted to the investigation of cognitive strategies of learning and remembering. The effects of such strategies have been

verified in connection with the learning of word pairs and lists (Anderson, 1970; Bower, 1970) as well as with prose learning (Levin & Devine-Hawkins, 1974; DiVesta et al, 1973). The technique of study skills described by Robinson (1946) called SQ3R has had remarkable durability, and appears in modified form in a recent text on cognitive psychology (Anderson, 1980). In recent years, more ambitious research projects have been undertaken to design training programs with the specific intention of teaching learning strategies and evaluating their effectiveness. Some of these efforts are described in a book edited by O'Neil (1978).

Dansereau (1978) describes a program designed by him and his co-workers to teach college students cognitive strategies of learning and retention. Instruction was developed for the following categories called primary strategies: (a) comprehension and retention strategies consisting of paraphrase-imagery, networking, and analysis of key ideas; and (b) retrieval and utilization strategies using such techniques as breaking questions down into subqueries and employing contextual cues. Other components were called support strategies, which included (a) cultivating a positive learning attitude, (b) concentration (coping with distractions), and (c) monitoring the progress of learning.

A number of additional varieties of learning strategies have been suggested, some of which continue under active investigation. Among these are elaboration strategies (Weinstein, 1978), anxiety reduction and self-monitoring skills (Richardson, 1978), goal imaging

(Singer, 1978), inferring deep-structure trace from surface structure (Brown et al, 1978), and several varieties of self-programming skills (Rigney, 1978). The work being done in this field of "learning strategies" has surely accomplished the identification of strategies that are learnable. Much additional research is needed to assess their effectiveness as components of instruction in the learning of educationally realistic tasks in the outcome categories of verbal knowledge and intellectual skills. Learning strategies enhance the effectiveness of learning and remembering of material such as word lists primarily because they make possible meaningfully organized encoding. Effective strategies for the learning of material which is itself meaningfully organized may be more difficult to discover, and their influence may turn out to be inherently weaker.

Problem solving. By making an intensive analysis of an individual's solution of the Tower of Hanoi problem, Anzai and Simon (1979) provide an account of the "learning by doing" of successively more complex cognitive strategies. Initially, a strategy of selective search was employed in avoiding bad moves. The problem solver was then able to develop a strategy of employing recursive sub-goals. Still another useful strategy was the chunking of moves. And finally, a particular sub-goal strategy (in this problem, called the "pyramid subgoal" strategy) was generated, making possible a particularly effective set of solution moves. In general, this account provides evidence that individuals are capable of transforming strategies, retrieving stored memories of strategies and problem procedures, and proceeding from looking ahead to looking backward.

Simon (1980) reviews and comments on recent evidence regarding the learning of general problem-solving capabilities. While acknowledging the important role of accumulated knowledge, he disagrees with Goldstein and Papert (1977) in their assignment of primary importance to this factor. In addition, he states, there have to be processes for operating on that knowledge to solve problems and answer questions. Students need to acquire intellectual skills and to distinguish the learning of this kind of procedural knowledge from the learning of propositions (verbal knowledge). In addition, Simon sees the possibility that learners can acquire problem-solving strategies, including very general ones like means-end analysis, by practice with the working of examples and the explication of problem-solving principles.

Metacognition

In a series of articles Flavell (1976, 1978; Flavell & Wellman, 1977) has described and exemplified a domain of intellectual functioning called metacognition. Although originally concerned with metamemory (Flavell & Wellman, 1977; Brown, 1978), the ideas have been elaborated to include a greater range of cognitive phenomena. The categories of knowledge about one's own cognition, according to Flavell, include sensitivity, knowing what situations call for intentional cognitive activity; person variables, knowledge of those attributes that influence learning and memory; a task category, referring to characteristics of the intellectual task which influence performance; and procedures for solution, or strategies. These metacognitive phenomena make possible cognitive monitoring (Flavell 1978, 1981) which can influence both the course and the outcome of cognitive

activity. A comprehensive review of metacognitive effects, particularly as they pertain to learning and remembering, is by Brown (1978). Evidence is included on the effects of knowing one's knowledge state, of prediction of intellectual performance, of planning ability, and of checking and monitoring cognitive activities. Results of studies of training metacognitive sensitivity and strategies are also summarized and interpreted.

Obviously the concept of metacognition raises the sights of research on cognition well beyond the scope of work on traditional memory tasks. Knowledge of the conditions that affect the acquisition and employment of knowledge may be obtained through experience or as a result of deliberately planned instruction. Such knowledge can be used, presumably, as a basis from which to originate the cognitive strategies which affect the processes involved in learning, remembering, and thinking. Presumably, experienced learners and thinkers are accustomed to engage in cognitive monitoring and in the use of (meta) cognitive strategies. Young children and other inexperienced learners can be trained to employ these strategies to good advantage, as the work of such investigators as Campione & Brown (1977), Belmont & Butterfield (1977), Markman (1977) and others has shown. Future research may be expected to illuminate further the specific nature of effective metacognitive strategies.

Schemata

The views of several cognitive theorists converge in proposing that knowledge is represented in human memory as semantic networks called schemata. As a network of concepts or of propositions (Norman

et al, 1976), a schema makes possible interrelations of elements of information about a topic, represents important features, functions, rules for selection and use of the conceptual unit. A "functional" schema may in addition represent a set of conditions and the events of a procedure. Similar in conception is the description of schema provided by Rumelhart & Ortony (1977), which states that schemata are data structures for representing generic concepts, applicable to objects, situations, events, sequences of events, actions, and sequences of actions. While acknowledging the work of Bartlett (1932), these authors consider their notion of schema to resemble more closely that of Kant (1963). Schemata function in the storage of knowledge, in comprehension, in making inferences, and also in organizing action. Anderson (1980) considers a schema in its basic sense to be a "collection of feature sets," forming a category. Concepts are learned as the learner picks out correlations of features in the environment and develops categories around these correlations. Schemata may also be formed in more complex domains of cognition. Rumelhart & Norman (1978) propose that learning may take the form of accretion of instances to a schema, "restructuring" by the creation of a new schema, or "tuning," which refers to modification of the variables within a schema without changing its basic structure. In the work described by Schank & Abelson (1977), the educationally important idea of understanding is reflected in schemata that are distinguished as scripts, plans, and goals.

For instructional psychology, the implications of the schema conception would appear to be these: (a) Newly learned information is stored by being incorporated in one or more schemata, which have been

formed by previous learning. (b) In general, as Bartlett's (1932) work showed, recall of previously learned verbal information is strongly influenced by schemata; remembering is a "constructive" act. (c) A schema not only helps retention of new material by providing a framework for its storage; it also alters the new information by making it "fit" the schema. (d) The schema, based as it is upon prior learning, makes it possible for the learner to make inferences which "fill the gaps" in stories or other expository prose. (e) Schemata are organized not only in terms of verbal (declarative) knowledge, but also as components of intellectual skills (procedural knowledge). (f) Learning how to evaluate and modify one's own schemata is a matter of considerable importance to the student; the instructional requirements of this activity are not yet well understood.

Mental Models

A form of schema having particular significance for the learning and performance of complex tasks is called a mental model. Johnson-Laird (1980) demonstrates the usefulness of a mental model in overcoming what he calls the "figural effect" in syllogistic inference. This effect is shown as a bias when people draw conclusions from "Some A are C" and "All C are D"; the conclusion "Some A are D" has a high frequency, whereas the equally valid "Some D are A" is very infrequent. This and other inferential flaws can be avoided, according to Johnson-Laird, by employing a mental model which sets up identities among imagined people in an imagined room. Imaginal steps are then taken with these identities to test whether they can be destroyed without doing violence to the meaning of the premises. In other words, a

"thought experiment" is done to carry out a comprehensive destructive test of the various identity models. The result is a complete set of valid inferences, arrived at through the mental models.

Another investigator who has expanded and clarified the meaning of mental models is Gentner (1977, 1981). She proposes that scientific models, in the form of analogies, may be considered as structure-mappings between complex systems. The system to be understood is new or abstract, and the "base system" in terms of which the target is described is familiar, and sometimes visualizable. An example of a complex analogy is the solar system model of the hydrogen atom. Desirable characteristics of analogical models, according to Gentner, are <u>clarity</u> (well-specified base and clearly defined correspondences) and <u>richness</u> (the quantity of predicates). As for the kinds of predicates to be mapped, they vary in <u>abstractness</u> and in <u>systematicity</u> of the mapping relations. This description is intended to distinguish the kind of metaphor (analogy) useful for scientific thinking from other "literary" metaphors. The properties described may be applied to naive models of scientific phenomena, to those of experts, and perhaps to illuminate the differences between them.

The role played by mental models in instruction is discussed under the title <u>work models</u> by Bunderson et al (1981). These authors consider that the "lexical loop" which results from a task analysis of job activities, while yielding descriptions of skills and knowledges, may leave out the work models which guide the performances of "experts." Such models may be conversational, used to define terms and situations; procedural, as exhibited in simulations; or causal, and hence used to

work out causal principles "in the head."

Work models are established by means of experiental learning, in which all possible attributes of the work setting are represented. When complete, they closely approximate the work domain of the "expert." In designing a complete instructional program, total practice situations often need to be broken down into situations of decreasing complexity. The authors foresee the particular usefulness of the videodisc in obtaining representations of work models for training and testing.

The current research trend may be seen as one of clarifying the meaning of mental models, perceiving where they are involved in human activities, and how they may be employed to make instruction more effective. It is tempting to speculate that such models, considered as one variety of schemata, may actually constitute the basis of logical thought, of scientific invention, as well as of expert job performance in any field. Mental models must surely be intensively explored as potentially essential components of instruction of every variety.

Knowledge Compilation and Optimization

In connection with their studies of problem solving in plane geometry, Anderson et al (1981) introduce some ideas which pertain to the consolidation, application, and generalization of knowledge. In other terms, they relate to the instructional event which Gagné (1977) calls "enhancing retention and transfer." Anderson and his co-workers propose that students first encode intellectual skills as declarative information (verbal knowledge) within semantic networks. When such knowledge is used, general interpretive procedures apply it to the

features of particular situations. As the knowledge is employed many times in a particular way, new procedures are developed which apply it directly without the interpretive step. This is the aspect of learning called knowledge compilation, and it consists of the two processes of composition and proceduralization. Composition reduces a series of intellectual skills to a single step. Proceduralization creates intellectual skills with knowledge formerly retrieved from long-term memory built into them, leading to their increased automatization (Neves & Anderson, 1981).

When skills are proceduralized, this is not enough to guarantee successful solving of problems. Knowledge optimization implies other processes. Experienced problem-solvers, in an activity such as generating plane geometry proofs, appear to be using heuristics of search which enable them to try the right inferences first. Such heuristics are acquired, it is hypothesized, by a process of generalization based on comparison of problems and their solutions; by the process of discrimination which places restrictions on the range of applicability of procedures; and by the process of composition, which leads to the formation of multiple-operator sequences.

Whether or not the initial stage of declarative encoding turns out to be a necessary phase of intellectual skill learning, these authors have directed attention to the processes of learning which occur subsequent to that event which may be called "initial acquisition." These additional learning processes, which presumably occur as the learner continues to practice with varied examples, are those

which lead to heightened retention and to more highly probable transfer of skills to novel instances and situations. They appear to be of great importance to the understanding of instruction, and are obviously in need of increased research attention.

Automaticity of Cognitive Processes

It is a curious and somewhat ironic circumstance that the idea of automaticity, so clearly described in James (1896) chapter on Habit, and so long proscribed as a phenomenon for investigation during the behaviorist era, should again come to prominence as a process of considerable importance to human cognitive activity. According to modern views (Anderson, 1980; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977; Spelke at al, 1976), cognitive processes have two processing modes: controlled and automatic. Controlled processing demands much attentional capacity, is serial in nature, and is frequently (at least) conscious. Automatic processing demands little attention, is parallel in its operation, and difficult to alter or suppress. Automatic processing occurs not only in the early perceptual stages of cognition, but also in later stages, as exemplified by the automatization of well-practiced skills. A number of subjects of school learning may be influenced by automatization. Thus, facile reading is considered to be affected by the capability of automatic decoding (Perfetti & Lesgold, 1981). Many of the operations of arithmetic would appear to depend upon certain "identity rules" which, if they are not automatized, greatly slow the processes of mathematical problem solving (cf. Resnick, 1981). The implications are that some part of instruction

in the realm of intellectual skills must serve "bottom-up" needs. Some skills need to be practiced until they become automatic, if the learner is to make satisfactory progress in "higher-level" learning.

Student Characteristics

Many kinds of student characteristics have been studied in their relation to achievement and other outcomes of schooling. Some characteristics are viewed as unalterable, more or less permanent traits to which varieties of instruction are possibly adaptable. Other characteristics are more or less stable, but their alterability through instruction or experience is questionable, or at least not firmly established. Perhaps most interesting of all to instructional psychology are personal qualities that can demonstrably be changed by instruction or training, and which then serve as positive factors in their influence on achievement.

Mental retardation continues to be a way of categorizing certain unalterable characteristics of students, related to difficulties or deficiencies in many kinds of school tasks (Allington, 1981; Sternberg, Epstein, & Adams, 1977). The use of this description is nowadays sometimes replaced by the phrase "learning disability," although it is perhaps preferable to consider the latter as an entity composed of separate areas of performance deficiency (Algozzine & Sutherland, 1977; Farnham-Diggory, 1978; Parrill-Burnstein, 1981). Vandenberg (1976) reviews some studies of fraternal and identical twins on word learning, trail-finding, and concept formation tasks which he maintains

provide strong evidence for inherited differences in intellectual processes.

A variety of semi-stable student characteristics are being studied in their relation to academic outcomes. Prominent among these are the self-concept (Ames & Felker, 1979; August & Felker, 1977; Eshel & Klein, 1981; Norem-Hebeisen, 1976; Shiffler et al, 1977), locus of control (Chapman & Boersma, 1979; Keller et al, 1978), style of attribution of success and failure (Andrews & Debus, 1978; Arkin & Maruyama, 1979; Frieze & Snyder, 1980; Fyans & Maehr, 1979), and a variety of other cognitive styles. Research on field-dependent and field-independent cognitive styles has been reviewed by Witkin and associates (1977).

Although some traits resist alteration, the alterability of others is open to question, and some investigators bravely undertake to change them. Several methods were tried by Fowler & Peterson (1981) in changing attribution to effort and reading persistence in children classified as "learned helpless." Such qualities as learned helplessness (Butkowsky & Willows, 1980), mathematics anxiety (Morris et al, 1978), and other varieties of cognitive style (Laosa, 1980; Lockheed, 1977; Shapson, 1977) are suggestive of the kinds of personal traits which may yield to special instructional treatments, and thereby make possible improved academic attainments.

Beyond the satisfaction of investigator curiosity, it is difficult to surmise a purpose for many of the published investigations of student characteristics. For any instructional system, there would appear to be three main courses of action possible with regard to the use of findings of correlations between any student characteristic and a desired educational outcome. First, students could be selected on the basis of a positively correlated trait. Although selection is undoubtedly done by schools, particularly by private ones, there does not appear to be much confidence that predictions of educational outcome can be raised worthwhile amounts beyond those already provided by measures of (a) general intelligence and (b) prior achievement.

Second, measures of student characteristics could be employed to make possible a match between "aptitude" and "treatment," and thereby bring about a general rise in the measure of achievement (or other outcome). Studies of ATI are yielding positive evidence of interactions, particularly for such student characteristics as anxiety, locus of control, academic self-esteem, and the like, and such instructional modes as lecture versus individual tutoring. It appears, however, that the traits themselves are so relatively situation-specific, and the instructional "treatments" so broadly structured that a truly systematic technology of adaptive instruction seems a remote possibility at best. The most feasible employment of ATI results to date would appear to lie in subtle and opportunistic adjustments of teacher strategies to individual students.

The third possibility is that student characteristics which are

more general than instructional content can be instilled in the learner by regimens of learning that range in time from very short to very long. Characteristics of this sort are usually not viewed as traits, but as learned capabilities. Specifically, they are intellectual skills, verbal knowledge, cognitive strategies, and attitudes. The importance to new learning of prior learning of these types of characteristics is an axiom of many instructional theories (as described in a previous section). If one is interested in systematic design of adaptive instruction, these are the student characteristics that can be depended upon. As yet, no other kinds of traits, whether alterable or not, have been shown to have an equal degree of usefulness to instructional design and practice.

Attribute-Treatment Interactions

Following publication of the essential handbook by Cronbach and Snow (1977), interest in attribute-treatment interaction (ATI) studies continues to be high. Many studies explore the attribute variables suggested by Snow (1976): anxiety (A_x), achievement via independence (A_i), and achievement via conformity (A_c), which are expected to interact with instructional treatments characterized by different "structure" and "participation." The other set of variables mentioned by Snow are mental ability of the sort called crystallized intelligence (G_c, verbal achievement), fluid intelligence (G_f, analytic reasoning), and spatial visualization (G_v).

Significant interactions seem to be usually found between anxiety and a "structured" approach to instruction; that is, high-anxious

students have better achievement in a teacher-centered approach, while low-anxious students do better in a student-centered approach. In Peterson's (1977) study of ninth graders in a social science course, stepwise regression analysis was used to reveal ATI's due to combinations of both structure and participation. Further results showed a complex Aptitude x Aptitude x Treatment interaction, in which high anxious - low ability students performed better in classes in which the teacher did not place high demands on them (low structure), whereas high anxious - high ability students did well in classes with high demands. Other studies exploring the interactions of anxiety and ability with instructional treatment are by Corno (1979), Peterson & Janicki (1979), Janicki & Peterson (1981), and Corno, Mitman, & Hedges (1981). Generally, the results are consistent with the notion that highly structured approaches are favorable for low ability students, but that this relationship is also influenced by anxiety in the manner previously described.

Beginning with an article on achievement-treatment interactions (1976), Tobias (1977a,b,c; 1979) has contributed a number of insightful reviews concerning anxiety and its interaction with instructional methods. He proposes a research model (1977c) which draws distinctions among the sites of influence of anxiety, during (a) preprocessing, (b) processing, and (c) after processing and before output. Tobias proposes that research seek out the relevant cognitive operations of these three stages; for example, at the processing stage, task difficulty, reliance on memory, and organization of the task.

Tobias (1979) goes on to propose a research emphasis on the treatment of anxious individuals in test-anxiety reduction programs.

The long-term educational goal of attribute-treatment interaction studies is the development of systems of instruction which are adapted to individual learner differences (Cronbach, 1967). The volume and variety of studies of ATI phenomena are extensive, and reviews devoted specifically to them are obviously of greater value to the researcher than a general review of this sort. Attribute variables have by no means "settled down," and new ones continue to appear, to compete with the more familiar variables of academic ability, self-concept, locus of control, achievement motivation, anxiety, and various "cognitive styles." Although feasible variations in instruction must surely be seen as part of the ATI problem, equally diverse variations in instructional modes and methods characterize studies in this area: lecture vs. discussion, teacher-centered vs. student-centered, programmed instruction vs. reading, prescribed sequence vs. learner control, and a number of others. The identification of learner processing variables affected by variations in instruction is also in a somewhat undeveloped state: such variables as task difficulty, content preference, attention and memory demands appear as initial tries in a domain of variables as yet poorly defined.

The ultimate applicability of ATI research is worthy of some consideration. If indeed the relevant kinds of individual differences continue to proliferate, and new varieties of approach to instruction continue to be suggested, the whole enterprise of systematic adaptive

instruction may become impossibly complex for the classroom. Is this where the computer enters the picture? Perhaps so, but one should be reminded that there are some aspects of classroom instruction which computer-based instruction does not (and cannot) simulate, centered around the interpersonal student-teacher interaction. How can these be included in a system of adaptive instruction which is simultaneously taking into account a great variety of personal traits of the learner?

Another precaution for the guidance of research is suggested by other sections of this chapter. Interactions of treatments with those personal traits called "aptitudes" do not typically yield effects of great size. In the background of every investigator's experience is the well-established finding, which continues to appear, that the most powerful variables related to school achievement are (*a*) intellectual ability and (*b*) the accumulated effects of prior learning. Most investigators equate these factors with Cattell's (1971) fluid and crystallized intelligence. Whether or not the equivalence is seen, these two factors continue to exert the strongest effects on the outcomes of student learning. Instructional systems which can adapt to these two human characteristics (whether by computer or by human action) would appear to have some likelihood of success in assuring student achievement.

Alterable Student Characteristics

Previously learned schemata. A number of studies attest to the importance of previously acquired memory schemata to the learning of new

verbal knowledge. Schemata are collections of organized concepts that occur together and that come to act as unitary "higher-order" concepts. They thus affect the encoding of new to-be-learned information. The strong effects of pre-existing schemata on both recognition and recall of prose passages is shown by a number of studies (Anderson et al, 1977; Anderson et al, 1978; Bower et al, 1979; Grabe, 1979; Pichert & Anderson, 1977; Spiro & Tirre, 1980). Evidence has been obtained that a prose passage may be stored in different memory locations, depending upon whether it can be related to previously stored knowledge (Royer et al, 1978). Other evidence indicates that information stored in accordance with a schema can be retrieved in terms of an entirely different schema (Sherman & Kulhavy, 1980), implying flexibility of encoding.

The Thorndyke & Hayes-Roth (1979) study of prose learning indicates that a familiar schema facilitates memory access at retrieval. In addition, however, when different contexts share the same schema, interference occurs among concepts. Interference has been shown to result from a conflict in retrieval between familiar and unfamiliar schemata (Lewis & Anderson, 1976; Royer et al, 1977). As the investigation of Smith and his co-workers (1978) demonstrates, thematic integration of newly learned facts can overcome such interferences. These various investigations of schemata are just beginning to lead to research questions of central importance to instructional psychology: Can we now deliberately teach new schemata which will facilitate the learning and retention of new information? (Anderson, 1981).

Advance organizers. Exactly how one would go about providing learners with schemata, or "ideational scaffolding," or "cognitive structures" which will predictably aid the learning of specific kinds of new verbal knowledge remains a lively subject of current investigation, still in need of further clarification. Anderson et al (1978) find Ausubel's justification for the advance organizer insufficiently convincing from a theoretical standpoint. Ausubel (1978, 1980) recalls again the description of his original article (1960) which states that advance organizers "mobilize whatever relevant subsuming concepts are already established in the learner's cognitive structure and make them part of the subsuming entity" (p. 270). It may be noted that this disagreement itself appears to be re-emphasizing the role of previously acquired knowledge which is already in the learner's memory, rather than addressing directly the question of how to instruct in knowledge structures which will assist in the acquisition of new knowledge.

Evidence of the positive effectiveness of advance organizers for learning and retention accumulates in studies of computer programming (Mayer, 1976, 1978, 1980; Mayer & Bromage, 1980), social studies concepts (Lawton, 1977), and television instruction (Nugent et al, 1980), among others. Reviews of recent evidence have been made by Mayer (1979a,b), by Hartley & Davies (1976), by Lawton & Wanska (1977), and by Luiten and co-workers (1980). It is of interest to find evidences of those conditions in which advance organizers do not work well (cf. Carter & Carrier, 1976; McDade, 1978), and also of some negative attitudinal effects (Nugent et al, 1980).

Mnemonics. Mnemonic strategies, particularly the keyword method, have been previously investigated by Atkinson & Raugh (1975; Atkinson, 1975) as an effective way of learning vocabulary in foreign languages. In this method, a spoken foreign word is linked to an English keyword by a similarity in sound; the key word is linked to its English translation by a mental image. Several subsequent studies of the keyword strategy have yielded favorable findings, in connection with various foreign languages (Levin et al, 1979; Pressley, 1977a; Pressley, 1981; Pressley & Levin, 1978; Raugh et al, 1977) and associative linkings (Marsh & Desberg, 1978; Pressley & Dennis-Rounds, 1980). Higbee (1979) contributes a review of visual mnemonics, including a historical sketch. The effectiveness of the keyword method of learning foreign words on a word-by-word basis appears to be well established. The relation of such learning to the capabilities of understanding, reading, and conversing in a foreign language is a question which is not addressed by these studies. Thus, the larger question for instructional psychology, of how one best goes about learning a foreign language, presents many challenges for the researcher.

Cognitive strategies. The effect on learning and retention of various kinds of cognitive strategies is the subject of studies directed at a range of students from kindergarten to college. Yussen & Bird (1979) found a reasonable amount of understanding of factors affecting cognition and memory in young children. Strategies of remembering were taught to retarded children in studies by Brown & Barclay (1976) and by Brown et al (1977), but they tended to have short-lived effects.

In early learners effective strategies for recall include categorization (Westman & Youssef, 1976), rehearsal (Ferguson & Borg, 1976; Ornstein, Naus & Miller, 1977), attention broadening (Rydberg & Arnberg, 1976), and counting (Wilkinson, 1976), among others.

Imagery. Instruction in imaging was shown to improve retention of prose passages in eight-year-old children (Pressley, 1976). Practice in tracing correct pictures improved children's performance in a pictorial discrimination task (Levin et al, 1977). Investigations of imagery in children's learning, including imagery training, have been reviewed by Pressley (1977). Imagery induced by pictures made possible enhanced retrieval of animal properties by young children (Prawat & Kerasotes, 1979). Partial pictures designed to elicit visual imagery were found to improve retention of a story content (Ruch & Levin, 1979) in second-grade children, although other evidence confirms the ineffectiveness of imagery instructions in children of kindergarten and grade 1 (Dunham & Levin, 1979; Guttman et al, 1977; Levin & Pressley, 1978). Paivio (1980) comments on the usefulness of imagery as a "private audio visual aid," particularly in the recall of paired associates including foreign vocabulary words.

In summary, it would appear that visual imagery induced by instruction or practice functions well as a strategy in the learning and recall of word-word and picture-word associations, except in the case of very young children. Some evidence indicates that images can help the retention of prose such as stories, but again not in the very young. While imaging is a common phenomenon, evidence of its special

instructional usefulness in providing cues for retrieval (cf. Gagné & White, 1978) has not as yet been forthcoming. Such usefulness may possibly be confined to those learners possessing high visualization abilities (Ackerman, 1981).

Intellectual skills. Experimental studies of basic processes in rule learning continue to provide evidence of positive transfer produced by pretraining in subordinate (or prerequisite) rules and concepts. Examples of such studies are those by Lee (1979) with a complex rule-governed task, by Bowers (1976) in oddity problems, by Vorwerk (1979) with a geometry rule, by Wilkinson (1976) in class inclusion problems, by Murray et al (1977) for conservation problems, by Barnes (1978), Tyrrell (1977) and Cantor & Spiker (1978) in children's discrimination learning, and by Martinko & Clifford (1978) in the area conservation task. In reading instruction, research confirming the subordinate-skill status of phoneme analysis and blending is reviewed by Resnick (1981) and by Williams (1980), and is discussed in terms of an interactive theory of reading (Rumelhart, 1977) in a recent volume edited by Lesgold & Perfetti (1981). Orthographic, syntactic, and semantic identification also occupy the role of subordinate skills in the interactive view of reading (Baron, 1979; Isakson & Miller, 1976; Lovett, 1979; Wisher, 1976). Intellectual skills contributing to problem solving in physics have been identified by Larkin & Reif (1976). The positive transfer effects of subordinate skills in other varieties of problems were shown in studies by Rogers & Wheeler (1977), Siegler & Atlas (1976), and Parrill-Burnstein (1978). The functioning of rules

and their relation to cognitive strategies in solving geometry problems was investigated by Greeno (1978a,b) in articles that clarify the role of different cognitive structures in problem solving. Some instructional implications of these matters are discussed in relation to problem solving by Gagné (1980a).

Verbal knowledge. Accumulated verbal knowledge (verbal information) is one kind of learned capability that can have a positive effect on the learning of new instructional material. It is perhaps not surprising, but worthy of note, that verbal knowledge is found to be positively related to the retention of word lists in cued recall (Ceci & Howe, 1978). Vocabulary scores, indicators of amount of stored knowledge, have long been known to correlate highly with reading comprehension (Davis, 1968). The specific influence of prior knowledge about a topic in improving recall of new learning (from reading) about the topic has been verified in studies by Spilich, Vesonder, Chiesi, & Voss (1979), and by Voss, Vesonder, & Spilich (1980).

Instructional Techniques

Of central importance to instructional psychology are questions about the manner in which the events of instruction are designed and delivered. Investigations have focused on the role of goals, objectives and learning hierarchies in the design of instruction, the organization of content, the use of media, and the role of illustrations and formating. Research studies show a current tread of interest in practice and feedback, including the use of adjunct questions. In nearly every instance, the reported research has been conducted with

mediated (primarily print) instruction, as opposed to teacher or instructor-delivered instruction.

Goals and Objectives

Nearly every instructional design effort begins with the identification of a goal. The goal should be specific enough so that the instructional designer can determine the subordinate competencies that will be required of the learner. But what about providing a statement of the goal to the learner? Studies by LaPorte & Nath (1976), Rosswork (1977), and E. D. Gagné et al (1977) show that prestating the instructional goal for the learner definitely influences the learner's performance. In general, when learners were informed of a "hard goal," e.g., answer 18 of 20 questions, they performed better than students who received nonspecific, less-difficult-to-achieve goals. The research by E. D. Gagné et al has shown that the manner in which the goals are stated influences how the learner attempts to organize the information. Two studies by Rothkopf (Rothkopf & Billington, 1977; Rothkopf & Koether, 1978) demonstrate that students are disrupted in their studying if there is not a match between the goals and information that is presented.

Closely related to goals are statements of objectives for the instruction. Like goals, they are an aid to the designer, and a potential aid to the learner. Melton (1978) has reviewed the controversy between those who see objectives as indicating to the learner what is relevant, and those who see them as suppressing students' incidental learning. Melton indicates that the issue has been

oversimplified. There are numerous conditions which seem to affect the influence of objectives on student learning outcomes: student interest, clarity and number of objectives, and location and frequency of insertion of objectives in the text. Studies dealing with the location of the objectives in the text have been reported by Kaplan (1976) and Royer (1977).

Analysis of Components

An area of continuing interest is task analysis. Studies by McMurray et al (1977) and Stephens et al (1981) indicate the benefits of an analysis of the cognitive operations required to reach specified levels of mastery. Both projects used task analysis as the starting point for their instructional projects.

A prominent method of identifying subskills for an intellectual skill is hierarchical analysis. Cotton et al (1977) review the original definition of a hierarchical structure and consider the psychometric and experimental evidence for specific structures. They encourage consideration of alternative routes in the hierarchy. Studies reported by Bergan (1980; Bergan & Jeska, 1980) advocate the investigation of alternate models of hierarchical arrangement of skills, while studies by White & Gagné (1978), Kee & White (1979), and Dick (1980) describe simplified methods of validating hierarchies. The evidence seems to indicate that empirical data can be used rationally to modify hierarchies, and in turn can be of aid in identifying and sequencing the skills to be included in an instructional sequence.

Organization of Content

Comprehension of prose passages, and their learning and retention,

can be facilitated when the passages have a high degree of organization. The nature of the organization may be structural in the sense of linguistic structure (Danner, 1976; Glynn & DiVesta, 1977; Mandler & Johnson, 1977; Yekovich & Kulhavy, 1976), or semantic structure (Glenn, 1980; Jordan, 1980; Mosenthal, 1979; Thorndyke, 1977), or even physical (Fuqua & Phye, 1978; Reitman & Rueter, 1980). Contextual organization that is superordinate to the to-be-learned material has been shown to result in greater learning and retention than a less well organized context (Arnold & Brooks, 1976; Gardner & Schumacher, 1977; Tenenbaum, 1977). Kulhavy et al (1977) found that free recall of a passage was improved following the use of either semantic or temporal organization. Learner-generated organization in the form of topic sentences, headings, related sentences, and unrelated sentences was examined by Dee-Lucas & DiVesta (1980), who found recall to be highest with learner-generated topic sentences. Royer & Cable (1976) studied the effect of an initial passage on the learning attained from a different abstract second passage. Greater retention was found following the reading of initial passages that were (a) abstract with illustrations, (b) abstract with analogies, or (c) concrete, as compared with (d) an unembellished abstract, and (e) a control passage on an unrelated topic.

Besides their effect on the learning of prose, organized presentations of various sorts affect the acquisition of intellectual skills, as might be expected. Tennyson and co-workers (1980) found that simultaneous presentation of coordinate concepts (types of reinforcement

and punishment) yields better learning than successive or collective presentation. Other presentation strategies for the presentation of concept instances were investigated by Park & Tennyson (1980) and by Carnine (1980). Stimulus organization was found by Rosenthal & Zimmerman (1976) to be an aid to the learning of a concept by fourth-grade children, but not an aid in enhancing transfer of learning. Gliessman & Pugh (1978) found that an advantage for high-structure films in the acquisition of teacher-behavior concepts did not hold up in posttest scores.

Despite the variety of meanings that may be assumed by the phrase "content organization," it appears that almost any structure which is imposed on the presentation of materials to be learned is helpful for both learning and retention, when one is dealing with verbal knowledge. While advantageous effects of organization are to be expected, a systematic description and classification of the dimensions of "organization" has yet to be formulated and tested. The situation for the learning of concepts and rules is a different matter; in that domain, organization must deal with the sequence and variety of rules and examples, concerning which much is already known (see, for example, Klausmeier et al, 1974; Markle, 1978; Merrill & Tennyson, 1977).

Cueing Systems

Another method of imposing organization on prose is through the use of typographical cues. The use of such cues as underlining and paragraph headings has assumed a new significance for investigators interested in the effect of these cues on learners' information

processing (Glynn & DiVesta, 1979). The use of cues in the design of instruction has been described in a book by Hartley (1978) and in an in-depth article by Wright (1977). Research studies have been reported on the facilitative effects of paragraph headings (Doctorow, Wittrock, & Marks, 1978; Sjogren & Timpson, 1979), underlining key phrases (Fass & Schumacher, 1978), special formats for numerical data (Macdonald-Ross, 1977), and segmented phrases and indentation (Frase & Schwartz, 1979).

Instructional Media

In recent times, investigations comparing different media have been replaced by studies of media which supplement other instruction, or which focus on the specific attributes of a medium for enhancing a particular type of learning outcome (Salomon & Clark, 1977). The evidence is clear that learners, particularly adults, can learn from nearly all media. For example, Cohen, Ebeling & Kulik (1981) report the results of a meta-analysis of 74 studies in which visual (film and TV) college instruction was compared with conventional teaching. The visual instruction had no differential effect on learner attitudes, achievement, or course completion.

Research with media as a supplement to regular instruction has shown positive results for various combinations. Rankowski & Galey (1979) used television and slides to supplement a descriptive geometry course and found significant effects on achievement and attitudes; Roberts (1980) examined 34 studies in which electronic calculators tended to enhance computational performance but had little effect on

conceptual learning or general attitudes toward mathematics; Schwartz & Kulhavy (1981) investigated the advantages of providing learners with a map of an island while they listened to a narrative of events occurring on the island; and Farnum & Brigham (1978) found significantly better performance for students who received study guides as compared to those who didn't. In a somewhat similar study, Main & Griffith (1977) showed that the use of print supplements with Navy instruction resulted in equal performance and less learning time when compared with audiovisual supplements.

Current research on media often involves an investigation of the interaction between specific media attributes and learner characteristics or capabilities. Aptitude/treatment studies are cited elsewhere in this chapter. Of note however, is Magoon & Raper's report (1977) on the development of procedures to test six different learning modalities: visual, auditory, audiovisual, vocal, motor and tactile. In the validation of the instruments it was shown that for a verbal information learning task, the visual and auditory modes were superior to the others. The procedure used by Magoon & Raper should be generally useful to those conducting ATI studies.

Typical of recent studies on media and their overall effects is that reported by Meringoff (1980). Children were either read a story from an illustrated text or watched a comparable television tape. There were marked differences in the two groups. The television watchers remembered more action, made better elapsed time estimates, and relied more on visual content as the basis for inferences. In

contrast, the children to whom the story was read recalled more vocabulary, made inferences on textual content and personal knowledge, and made more personal comments about the story. Studies such as this suggest the importance of selecting particular media to optimize different types of learning outcomes.

Instructional Motivation and Games

According to a study of elementary classrooms in California, puzzles and games are widely used by individual pupils, and are valued by teachers as adjuncts to instruction (Baker et al, 1981). Yet their use is often related negatively to student performance. However, this need not be the case. The use of games to provide intrinsically motivating instructional environments is discussed by Malone (1981), followed by accounts of a survey of computer game preferences and studies of particular computer games. Factors found to be contributing to the strength of intrinsic motivation are described under three headings: challenge, fantasy, and curiosity. Challenge includes goals which are personally meaningful, engaging the individual's self-esteem, and having uncertain outcomes. Some games present problems in terms of the elements of the fantasy world; in the Snoopy game, Snoopy shoots at the Red Baron on a number line. Motivation is often improved by the addition of intrinsic fantasy. Curiosity is evoked when games provide an optimal level of informational complexity. Motivation is enhanced by games when their environments are novel and surprising. With these conclusions, Malone provides a comprehensive framework for designing instructional games that are intrinsically motivating.

The Role of Illustrations

A basic component of mediated instruction is often a picture. Early research on the effect of pictures was rather discouraging (Duchastel, 1980), while more recent studies, according to Fleming (1979) tend to show the instructional effectiveness of pictures.

Much of the recent research indicating a facilitating effect of pictures has been conducted by Levin and his associates. Levin & Lesgold (1978) report that consistent factual recall learning gains can be shown when fictional narrative passages are presented orally to children along with pictures that overlap the story content. These results hold for long-term (3-day) retention (Peng & Levin, 1979), and they also apply to mental retardates (Bender & Levin, 1978). Levin has also shown that detailed pictures facilitate recall of both central and incidental information (Levin, Bender & Pressley, 1979), and that pictures are more effective than repetition in facilitating recall (Levin, Bender, & Lesgold, 1976; Ruch & Levin, 1977).

Other researchers (Haring & Fry, 1979) used written prose with elementary age children. They found that pictures facilitated the immediate and delayed recall of main ideas from a passage but did not help with the recall of nonessential details.

Duchastel (1980) has called for the functional analysis of the role of illustrations in the learning process. In an earlier paper (1978), Duchastel indicates that illustrations can: (a) gain attention, (b) help explicate that which is to be taught, and/or

(c) facilitate retention. A study by Rigney & Lutz (1976) used graphic presentations via a PLATO CAI system to facilitate the explanation of concepts in electrochemistry. Conceptual and topographic information was elaborated by illustrations or verbally. The results with 40 college students indicated that those students who studied the illustrations had significantly greater knowledge, comprehension and application of concepts, and found the instruction more enjoyable. They also indicated having experienced significantly more mental imagery. Studies of this type will increase our understanding of the functional role of illustrations in instruction.

Practice and Feedback

Appropriate practice and feedback are two of the primary events of instruction. Practice, or participation by the learner, is typically an integral part of the initial learning process. Questions of interest to researchers are how much and what type of practice and feedback are best for the learner. While repetition is the most typical form of practice, Gallimore, Lam, Speidel & Tharp (1977) found that kindergarten students learned the names of shapes better by elaboration than from overt rehearsal. Elaboration consisted of connecting the name and a common object in a story. Yoshida (1980) manipulated the difficulty of the practice activities to assess its effect on learner performance. Students who were learning division were provided with either a fixed range of easy-to-difficult practice

problems or a homogeneous set of items the difficulty of which was determined by each student's performance on the previous day. Performance on the posttest indicated no difference on easy items; but an advantage on the difficult items for students who had the full range of practice each day, as opposed to those who had individualized tailoring of their practice.

Direct participation as a type of practice has been investigated by Swanson & Henderson (1977) and Henderson & Swanson (1978). Their interest is in the use of television as an instructional system and the use of modeling as an instructional technique. Their research suggests that such instruction is significantly enhanced with young children if they are provided the opportunity to perform the behaviors displayed by the televised models.

Questions. Perhaps the most heavily investigated form of practice has been adjunct questioning. The insertion of questions into a text was first suggested by Pressey, later became a form of programmed instruction, was studied by Rothkopf as a form of mathemagenic behavior, and is now of interest to cognitive psychologists as a means of investigating schemata. A number of reviews of the effects of inserted questions have been published recently (Andre, 1979; Dayton, 1977; Rickards, 1979; Rickards & Denner, 1978). Rickards & Denner (1978) particularly note the switch from interest in the effect of location and frequency of questions on verbatim learning to cognitive

psychologists' interests in the effect of the level (or type) of question on text comprehension. Andre's review (1979) suggests that higher level questions tend to have facilitative effects on both reproductive and productive knowledge, and E. D. Gagné's review (1978) indicates the positive effect of questions on long-term retention.

Almost all studies have demonstrated the superiority of postquestions (as opposed to prequestions) when inserted into a text. For example, Sagaria & DiVesta (1978) showed that when intentional and incidental learning were assessed, postquestions and no questions were superior to prequestions. The findings of Rickards (1977) run contrary to this conclusion, indicating that certain types of higher level questions may be more effective in the prequestion location. In an earlier study (Rickards, 1976), college students were given either conceptual or verbatim questions in either the pre-passage or post-passage location. In general, the conceptual prequestions produced higher recall than conceptual postquestions, while the opposite was true for verbatim questions.

Although some researchers have shown that the insertion of questions has either no effect on learning or a detrimental one, the majority of the studies show positive outcomes. Yost, Avila & Vexter (1977) gave seventh-grade science students questions of varying complexity in a programmed instruction text. They did significantly better than those who read paragraphs in the text or had no questions in the text, but there were no differences among the groups with different levels of complexity of questions.

Andre et al (1980) examined the effect of factual versus application adjunct questions on students' ability to apply the concepts being taught. In five of seven studies there were no differences in outcome resulting from the two types of questions; in two studies, the factual questions yielded superior performance. Rickards & Denner (1979) report a similar type of finding in a study of conceptual postquestions and underlining. Students who received the conceptual postquestions and underlined topic sentences in each paragraph, recalled fewer details of a passage than those who had no questions or did their own underlining.

Other studies show the positive influence of different types of questions. Two studies by Andre (1981; Andre & Womack, 1978) indicate the impact of paraphrased adjunct questions as opposed to verbatim questions. In the first study, those students receiving paraphrased adjunct questions did significantly better than other students on a posttest which contained unfamiliar paraphrased questions. This result was essentially confirmed in the 1981 study.

These studies suggest the importance of the similarity between the type of question used in the text, and the type used in the posttest. Two studies support this relationship. Reynolds et al (1979) compared students who received inserted questions with those who did not. Those who received the questions performed better on posttest items that were identical to the inserted questions, and also on unfamiliar items from the same categories as the inserted questions. Similarly, Ellis et al (1980) report a study in which the students who

had identical items on the posttest to those they had received as inserted items, did significantly better on the posttest than those students for whom 50% or 0% of the items were identical. This study contained seven lessons and lesson exams in which the item ratios remained the same over time. Thus, students could infer the relationship between the inserted items and the items on their tests, and make good use of this information.

Feedback. Knowledge of results (KOR) as a form of feedback to learners has long been known to have positive effects on learning. However, as Kulhavy (1977) and others have noted, researchers who have used programmed instruction as a vehicle for studying KOR have not always found it to have significantly positive effect. Kulhavy and his associates have reported several studies which may help to explain this discrepancy.

In a study by Kulhavy et al (1976) students read a 30-frame programmed text and either did or did not receive feedback after every response. Students rated their confidence in each response. High confidence responses which were correct in the text, also tended to be correct on the test, as would be expected. However, high confidence incorrect responses, on which the student was corrected in the text, tended to be answered correctly more often on the posttest as compared to incorrect responses in which the learner had little confidence. This outcome was interpreted by the researchers to reflect the greater study time given to high confidence incorrect responses. By contrast, feedback had little effect on low-confidence responses;

these occurred when students failed to understand the program content and thus had low confidence in their responses and spent less time studying the KOR. A similar study is reported by Kulhavy & Yekovich (1979) confirming the results of the 1977 study.

Classroom Processes

What aspects of classroom procedures or the customary behavior of teachers have an effect on the outcomes of instruction? A number of answers are suggested by research studies. For example, the effects of teachers' expectations were examined in a longitudinal study of British beginning elementary school children (Crano & Mellon, 1978), by means of a series of cross-lagged correlational analyses. Expectations of achievement and evaluations of social performances were identified as causal variables for children's achievement. When dealing with such labels as emotionally disturbed, mentally retarded, etc., the effects of teachers' expectancies were shown in their completion of referral forms after viewing a videotape of a normal fourth grader (Foster & Ysseldyker, 1976). Amount of interaction between teacher and individual student is another variable which has been found to affect student achievement (Firestone & Brody, 1975). Classroom observations indicate differences in interaction substantially influenced by race and sex (Hillman & Davenport, 1978; Leinhardt et al, 1979), in its relation to student achievement.

Differences in the verbal behavior of teachers in classrooms is frequently shown to affect student achievement; Winne (1979) has reviewed the research relating types of questions asked to level of

performance. Additional studies have shown the importance of providing the learner with precise descriptions (Smith & Cotten, 1980), and clear structure (Clark, et al, 1979). DiVesta & Smith (1979) demonstrate the importance of what is <u>not</u> said by showing that interspersing pauses in instruction can affect both immediate and long-term (2-week) recall with college students.

From a broader perspective, Ebmeier & Good (1979) taught teachers a model of good teaching, and found it effective in improving mathematics achievement of fourth graders. Everston, Anderson, Anderson & Brophy (1980) conducted an observational study of English and mathematics teachers. Effective teachers were found to be active, well organized, and strongly academically oriented. In a study of student ratings of instruction, Williams & Ware (1976) show that college students who received the most substantive information in their lectures performed best on achievement tests. Young children and special education students' behaviors have been shown to be significantly influenced by the competence of the teacher, i.e., one who avoids ambiguities (Sonnenschein & Whitehurst, 1980), and the repeated instruction to "work hard" (McLaughlin et al, 1977).

A review of teacher behavior studies by Brophy (1979) acknowledges the importance of factors involved in "direct teaching" (Rosenshine, 1979), but points out that these findings have come from studies of basic skills in the elementary grades. Context and process

variables may be of greater significance at higher grade levels, and deserve more extensive investigation.

A series of studies relating to direct teaching are those which employ modeling behavior by the teacher. Researchers in this area examine both Piagetian and Social Learning Theory (Bandura, 1969) propositions. Zimmerman & Kleefeld (1977) found that teachers do not spontaneously demonstrate modeling behavior, but when they are trained to do so, they are significantly more successful than their untrained counterparts. The direct influence of the model has been shown by Zimmerman and Blotner (1979) in their study of enhanced persistence by children, and by Brody et al (1978), who demonstrated that when descriptive adjectives were used by a model, their use by learners increased. Some studies have attempted to determine how instruction via modeling can be improved in effectiveness. When Swanson & Henderson (1979) compared televised modeling and televised modeling plus direct instruction, in the induction of complex seriation behavior, there was no difference in student performance. However, Brown (1976) found that when the model performed the activities, student achievement was significantly higher than when the model used only pictures or verbal instruction.

Several investigators have supplemented the modeling behavior of the teacher with direct activity by the learners— either in the form of imitation of the model during the instruction or through role-playing. While Zimmerman and Jaffe (1977) failed to find a significant

imitation effect in teaching children a rule learning task, Novak (1978) found that imitation training was more effective than modeling in teaching a verbal task to preschoolers. Social problem solving by third- and fourth-grade children was significantly enhanced when a televised model's instruction was supplemented with related role-play activities (McClure, Chinsky & Larcen, 1978).

Research on students teaching students has been underway for well over a decade (see Devin-Sheeham et al, 1976; Paolitto, 1976). At the elementary level, cross-age tutoring tends to be employed with mutual benefit to both the tutor and the pupil. Medway & Lowe (1980) found that students in a cross-age tutoring study attributed their success in learning to their tutoring partner and to their own efforts, rather than to their ability. With older learners, junior high and above, it has generally been found that predicted satisfaction and achievement as well as actual achievement are greater for the tutor than for the student (Rosen et al, 1977; Rosen et al, 1978; Bargh & Schul, 1980). Peer tutoring has been employed as a component of many forms of Personalized Systems of Instruction (PSI).

In the matter of grouping students, French et al (1977) report that the equal rewarding of all learners in a triad was superior to a winner-take-all strategy when teaching first and third graders. The importance of interaction among group members (3rd to 6th graders) has been demonstrated by Cloutier and Goldschmid (1978). At the high school and college levels the advantage of grouping during instruction has been shown in terms of better performance, enjoyment of tasks, and

certainty about answers (Garibaldi, 1979; Durling & Schick, 1976; McClintock & Sonquist, 1976). A review by Sharan (1980) compares the advantages of peer tutoring and grouping in the classroom, and suggests that the former may be superior for "low level cognitive learning" while groups may best facilitate higher levels of learning.

Applications of Instructional Psychology

Many of the researchers whose work is referenced in previous sections are primarily interested in understanding the psychological processes related to learning. Accordingly, typical research designs include several levels of the variable of interest which are assessed in terms of their effects on learner performance.

Rarely is the situation reversed. Rarely does the researcher say, "I have a learning problem. What instructional psychology principles can I utilize in the solution of this problem?" However, practitioners in schools, industry, and military organizations often find themselves confronted with just this situation. They are often confronted with the necessity of teaching new content or different learners, or are required to deal with fiscal or political realities that significantly change the learning environment. These practitioners, who often become "developers," must select from what is known in the field of instructional psychology to build or improve upon solutions to persistent problems.

In this section we describe four problems the solution to which has employed psychological principles. The first is that of selecting and sequencing appropriate content for inclusion in specialized

curricula; second, improving the effectiveness of operational computer-assisted instructional systems; third, a research-based method of improving the quality of instruction; and fourth, utilizing research findings in teacher inservice instruction. Each description includes a statement of the problem, a rationale for the psychological principle employed, and the outcome of the project to date. In none of these studies can the outcomes be solely attributed to the principle identified; many factors have contributed to the solution of each problem.

Applications of Hierarchical Analysis

How should one identify and sequence intellectual skills? This problem arises when instructional materials are to be developed in areas in which no instruction previously existed, or that which existed was unsatisfactory, or, as in the case that follows, a new medium of instruction is employed.

Since 1970 the Ontario Institute for Studies in Education has been involved with the schools and community colleges of Ontario in the cooperative development of computer-assisted instruction. In a recent report (Gershman & Sakamoto, 1980), CAI instructional sequences were created for thirty of the most important topics in intermediate mathematics including arithmetic, algebra, probability and measurement.

The development activities were conducted by joint teams consisting of OISE staff members and teachers from cooperating schools. Their basic approach was to cluster the skills to be taught into a terminal objective and one or more enabling objectives which represent skills that must be achieved in order to achieve the terminal objective. The objectives form a hierarchical relationship in which

subordinate skills must be achieved prior to the learning of superordinate skills (Gagné, 1968).

This analytic approach was especially critical in this project because it provided not only the identification of skills and sequence for teaching them; it also provided a branching rationale for the CAI lessons. For example, in a typical lesson, students may be asked if they can perform the terminal objective. If they can, they are shown the subordinate skills and asked which is the most difficult one they can do. Students are then sequenced through the hierarchy based upon performance on tests embedded in the instruction. The hierarchy is also used as a major component of the sequential testing strategy. It is estimated that this technique reduces testing time by 50 per cent.

The CAI mathematics curriculum which is based on the hierarchical analysis of each terminal objective was extensively evaluated during the 1979-80 academic year. From September to January over 2,000 Ontario students in 18 schools spent an average of four hours to cover an average of seven topics. Great variability was found in the number of topics covered by the students. Pretest-posttest analyses indicate there were significant gains for both CAI and comparison non-CAI students in the same schools; however, the CAI students gained significantly more. Attitude questionnaire results showed that 94 per cent of the students said CAI was "fun," "interesting," and 72 per cent said they liked math better with CAI. Similar results have been reported for the other courses developed by the OISE staff.

The U.S. Navy has also found it useful to incorporate the use of hierarchical analysis into the curriculum development process. The need for added instruction in basic skills has resulted from the Navy's inability to attract personnel with aptitude scores high enough to qualify them for entry into initial job training programs. One response to the problem has been reported by Harding, Mogford, Melching and Showel (1981). As contractors of the Navy Personnel Research and Development Center, they faced the task of identifying what basic skills should be taught to entering recruits in order to prepare them for the "A" (initial job training) schools.

The research team's most successful approach to identifying needed skills was that of first identifying the major learning tasks in each of four A School curricula. Based on this analysis, tentative sets of skills were identified which appeared to be prerequisite to the skills that had to be learned in the A School. The types of skills that were tentatively identified were: find information in a table, add numbers, read a setting on a micrometer, comprehend a written passage, and solve word problems.

A battery of test items was developed to assess these basic skills, as well as some of the vocabulary used in A School training programs. Specific tests were developed for each of four training programs. Test results from recruits who were qualified for A School and those who were not qualified were used to identify the specific skills to be included in the job-oriented basic skills (JOBS) curriculum.

These skills were clustered into modules. Certain skills were selected as terminal objectives and other skills arranged in a hierarchy of subordinate objectives. Other skills were inserted into the hierarchy when it became apparent that they were required prerequisites. The completed hierarchies included the identification of the skill in the A School to which the basic skills related, the hierarchical arrangement of the prerequisite basic skills, as well as the prerequisites to the prerequisites, i.e., the skills required of the learners in order to make initial entry into the JOBS program.

The hierarchies served as the basic design component which resulted in the development of instructor guides, student guides, lesson summaries, practice exercises, overhead transparencies, and various evaluation instruments.

A preliminary evaluation of the JOBS program has been reported by Baker and Huff (1981). The performance of students entering the JOBS program was compared with that of those who chose not to enter it, and with students who were qualified to directly enter an A School. The students in the JOBS courses demonstrated gains of about 42 points from pre- to posttests, and 95 per cent went on to complete the JOBS program successfully. Of the graduates of the program, 75 per cent then were able to graduate from A School. These percentages compare favorably with the qualified student graduation rate of 87 per cent. Eight months after graduation, the qualified group had approximately three times as many fleet discharges as did the JOBS group. While the results are supportive of the JOBS program, an experimental study has not yet been conducted which includes JOBS-eligible students who

do not get JOBS training but go directly to A School.

The OISE and JOBS projects are examples of two highly successful efforts which relied heavily on the hierarchical analysis of terminal objectives to identify the prerequisite subordinate skills and the appropriate sequence for those skills. Revisions of the hierarchies came about through the formative evaluation and revision of the instruction. The hierarchical approach, initially investigated as theory, appears to have served a very pragmatic role in these and many other instructional development projects.

Computer-Managed Instruction (CMI)

An area of increasing interest in recent years has been the use of computers in instruction. While research has been underway for over a decade (e.g., Dick and Gallagher, 1971), there has been a resurgence of interest because of the use by military agencies of both large computer systems and microcomputers in nearly every education and training setting. Investigators were initially interested in computers as instructional delivery systems because they made possible the automation of many of the behavioral principles of learning. More recently, cognitive psychologists have used the computer as a device to represent their theories (Greeno, 1978) or as a direct model of a problem-solving strategy (Alderman, 1978). Meta-analysis of research on college level computer-based instruction by Kulik, Kulik & Cohen (1980) indicates a consistent positive effect on both learning outcomes and attitudes, as well as a substantial reduction in learning time.

Numerous computerized learning systems are currently in use. One of the largest is the Navy's CMI system. By 1980, it had approximately

9,000 daily users from ten different technical training schools. Various evaluations of the system have demonstrated its general effectiveness, but users and observers agree that further improvements can be made. A study by Van Matre (1980) documented these needs. It included observations of the system in operation and questionnaires and interviews with CMI managers, instructors and students. The result of the study was the development of a list of priority projects which address student and system deficiencies and limitations.

A number of these projects have been conducted and the results of four of them have been reported. One dealt with the effect of altering student/instructor ratios, while another investigated the effect of different test item formats and procedures on student performance (see Van Matre et al, 1981; Lockhart et al, 1981). A third study by Hamovitch and Van Matre (1981) determined the feasibility of automating the testing of performance skills and knowledge, in comparison with the traditional manual testing and grading system. A fourth study, employing the direct application of previous findings of instructional psychology, attempted to increase the motivation of students who use the CMI system. It was observed that not all students progressed at their optional pace through the individualized course. An experiment was conducted by Pennypacker et al (1980) which drew upon the first author's prior work on charting student progress as a means of enhancing motivation.

A CMI course in basic electronics and electricity, taught in

Memphis, was used as the vehicle for the research study. Progress charts displayed the ratios of actual learning times to predicted learning times; in some groups they were shown periodically, in others when requested by the student. The outcomes of the study indicated no significant differences among groups on the final comprehensive examination. However, those students who were provided a progress chart only when they requested it, required significantly less time to complete the course than the other groups. The 10 per cent time savings represents more than one full day of training. If this outcome were replicated across all the students who take the course in a year, there would be a savings of over 20,000 training days. Both students and instructors were extremely supportive of the charting procedures.

A related set of research studies has been conducted on the appropriate role of the instructor within a CMI system (McCombs and Dobrovolny, 1980), and the application of learning (as opposed to teaching) strategies in a computer-based technical training system (McCombs, 1981). These studies focused on the Air Force's Advanced Instructional System which is a large-scale individualized CMI system. The latter study is of particular importance because it focuses upon the learning difficulties of lower ability soldiers in the all-volunteer military service. These students lack some of the basic skills, and they also exhibit motivation and study skill deficiencies.

In the research reported by McCombs, the criteria used to identify students who were performing unsatisfactorily in the AIS technical

training courses were criterion test scores, learning time, and dropout rates. These criteria were combined to identify the 25 per cent of the students with unsatisfactory progress. It was found that these students had little interest in learning the course materials; experienced high anxiety about the course and tests; had poor logical reasoning, reading comprehension and study skills; and tended to be the younger students having less educational experience.

A battery of measures was developed to be used on an ongoing basis to assess students' personal values and goals, psychological and vocational maturity, self-esteem, expectations about the military and training, responsibility for their own learning, ability to deal with stress and make decisions, achievement motivation or fear of failure, and problem solving skills.

A major component of the ongoing R & D effort has been the development of skill training materials, i.e., materials designed to aid learners to be more effective in the CMI environment. For example, one set of materials describes the requirements of a self-paced, individualized, computer-managed instructional setting. Within this set is a time management module which includes a charting of predicted and actual learning time similar to that described earlier by Pennypacker et al (1980). Four study skills modules emphasize reading comprehension, memorization, test taking, and concentration management. In each area there is an attempt to help students make their learning meaningful, so as to increase both motivation and comprehension.

A third set of materials has been produced by McCombs to help

students develop positive motivation and personal responsibility. The instruction deals with negative attitudes, values clarification, career development, goal setting and stress management. All of the instruction appears in printed, self-instructional format. It is designed to be easily readable with accompanying visuals; and it includes practice exercises. The modules vary in average learning time from 30 minutes to about four hours.

At this stage in the project the researchers are attempting to assess the facilitative effect of these specialized learning strategies materials in terms of learning outcomes, learning time, and attitudes. However, it will be extremely difficult to isolate the effects of any single module. Many observers would be required to determine changes in "process skills" which, in turn, result in outcome changes. There will be difficulty also in implementing an effective research design in an operational military training environment. The McCombs study exemplifies the application of instructional psychology principles to specific learning problems. In this case, deficient learning skills have been identified and instructional materials developed for students who are studying in a computer-based, individualized environment.

The Instructional Quality Inventory

A method of appraising the effectiveness of training has been developed by the Navy. The principal product is the Instructional Quality Inventory (IQI), adapted from one originated by Courseware, Inc., which is used by experienced instructional designers to improve the quality of existing instruction. Wulfeck, Ellis, Richards, Wood and Merrill (1978) report that a need existed for a quality control

procedure to insure the effectiveness of instruction developed by and for the Navy. The research literature was examined to identify valid principles for prescribing instruction. Techniques were developed which could be employed to determine whether or not instruction conformed to these principles.

The basic observations involve the confirmation that (a) stated objectives are job relevant, (b) test items assess the desired learning outcomes and are congruent with the objectives, and (c) course content matches the objectives and is adequate according to psychological principles of learning. When these conditions are not met in the instruction, revisions are to be made.

Perhaps of greatest interest to the instructional psychologist is the matrix of tasks and content which is used by the reviewer to examine the objectives, tests and instruction. The content of the instruction is classified as: fact, category, procedure, rule, or principle, and what the student has to do with the content (his/her task) is classified as: remembering, using, and using with an aid. The IQI tables indicate, for example, that an objective which involves the aided use of a rule should have certain properties which differ from objectives of other categories, such as using a rule without an aid. Similar tables are available for assessing the adequacy of test items and instructional strategies (see Fredericks, 1980).

The IQI procedures have undergone extensive formative evaluation and revision (Montague & Wulfeck, 1982). Workshops have been held with instructional designers to insure that the procedures are clear and useful. User manuals and training aids have been developed

(Wulfeck et al, 1978; Ellis & Wulfeck, 1978; Ellis, Wulfeck & Fredericks, 1979). While summative evaluation results from the use of the IQI have not yet been reported, this is a notable example of the incorporation of instructional principles into a training program in order to enhance instructional effectiveness.

Teacher Inservice Training

The final application study to be described is concerned with the problem of providing teachers with research-based inservice training. After extensive efforts to bring research findings into the classroom, Huitt and Rim (1980) report that the "methods and materials used by researchers to describe from limited observations the conditions and processes that can be generalized to the school year likely are more complex and time-consuming than is necessary for practitioners concerned with what is happening now to make for a better year" (p. 47). This observation was based upon the experience of implementing the Research for Better Schools (RBS) four-phase Instructional Improvement Cycle - a process which links research findings with classroom practice.

RBS, an educational research, development and service organization, worked out a process with local schools in which data are collected in classrooms on selected variables. These are equivalent to and compared with data from reported research studies. The teacher decides if improvements can be made in the classroom, and, if so, what change goals should be established. After the commitment to change is made, the teacher studies an array of alternative strategies which might be employed and selects the one which seems most promising. The final

cycle includes the implementation of the plan, another round of data collection, and further modification if the results warrant it.

In order to implement this process, RBS recognized the support role they would have to play. They began by conducting a rigorous examination of what is referred to as process/product research, i.e., the research that attempts to link specified teaching practices with successful learning outcomes. The most creditable reviews of this research were selected. These were used to identify areas of focus which appeared to have the greatest potential for instructional improvement in the classroom. The variables thus identified were: student engaged time, the overlap between content taught and content tested, and prior learning relevant to the task to be learned.

After these variables were identified, RBS developed instruments and procedures which could be employed by classroom teachers to determine the status of their classrooms on these variables. In addition, it was necessary to develop reference materials to be used by teachers in comparing their data with that reported by researchers. Rather than referring teachers to the original research reports, special graphs and tables were developed to facilitate both the comparison with the researcher's data, and the reaching of a decision by the teacher. The final component of the system is a set of strategies which suggest ways of implementing the various alternatives the teacher might select. RBS attempted to deal only with those strategies which had research support. The system has been documented by RBS in a series of manuals.

Initial results indicate that teachers can be taught to use the "engaged time" data collection system in less than ten hours. Huitt and Rim (1980) report initial informal success from the implementation of the student engaged time procedures in classrooms by the teachers. The total results of a formal evaluation are not yet available, but the researchers plan for combination of engaged time training with that on the importance of instructional overlap and on prior learning.

Summary of Applications

The studies reviewed in this section tend to lack the rigor of those reported in earlier sections. They are important because they provide an entirely different perspective on the field of instructional psychology. In each of these projects an instructional problem existed - how to identify and sequence content for intellectual skills, how to improve the effectiveness of a CMI system, how to appraise training effectiveness, or how to enhance the instructional effectiveness of teachers. In each project the investigators drew upon the existing research base in order to develop a solution. While not all instructional psychologists are likely to be concerned about the immediate application of their research findings, it is worth bearing in mind that application is the appropriate end-point for the research cycle, and often the beginning of the next.

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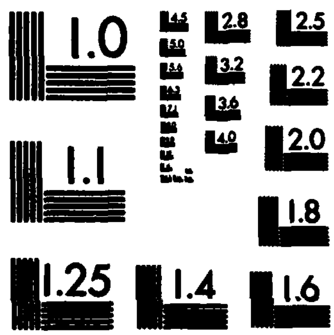
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